

# REVIEW OF NFPA 13 DRY SYSTEM WATER DELIVERY PROVISIONS *EXTENDED ABSTRACT*

by

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## INTRODUCTION

Schirmer Engineering Corporation (Schirmer Engineering) was retained by The Fire Protection Research Foundation (FPRF) as a Project Consultant for the project titled "Data Needs for NFPA Automatic Sprinkler Committees." This report investigates the NFPA 13, *Standard for the Installation of Sprinkler Systems* (2007 Edition) requirements for dry pipe systems having a maximum volume of 500 gallons without a quick opening device, and 750 gallons with a quick opening device.

The volumetric limitations of dry pipe sprinkler systems are contained in Sections 7.2.3 of NFPA 13. Per Section 7.2.3, all sprinkler systems are required to deliver water to the inspector's test connection within 60 seconds, except for systems with less than 500 gallons capacity and systems having a quick opening device with less than 750 gallons capacity. Section 7.2.3.6.1. permits listed calculation methods to be used to predict the water delivery time based upon the trip time, transit time and compression of air within a dry pipe sprinkler system.

Formulas are available to determine the flow of pressurized air out of an open orifice, friction loss as pressurized air flows through a pipe, and friction as water flows through a pipe. Theoretically, trip times of dry pipe systems can be calculated. Practically, manual calculations involve numerical analysis techniques that are extremely time consuming and are beyond the skills of most sprinkler system designers. Historically, most dry pipe sprinkler systems have been designed to 1) avoid having to meet the 60 second delivery time by limiting the system size, or 2) use past experience to determine appropriate the capacity limitations and hope the 60 second water delivery time can be met after the system is installed.

When the 60 second water delivery time could not be met, an exhaustor could be added at the end of the cross main to attempt to improve water delivery time. This produces a system that relies on the operation of both an accelerator and exhaustor. If the accelerator trips first, there is no guarantee that the exhaustor will trip because water filling the pipe system is counteracting the drop in air pressure needed to operate the exhaustor. In extreme cases it might be necessary to split the dry pipe system into two or more smaller systems to obtain 60 second water delivery time. This is a costly, time consuming modification.

The omission of the 60 second water delivery time has allowed the contractor an option to design with certainty, smaller systems (less than 750 gallons) in compliance with NFPA 13. Recently NFPA 13 was modified to allow the use of listed software to provide certainty that the completed system would comply with NFPA 13. Software development for this application is in its infancy and while at least one software program is available, it is expensive and limited in scope. The currently available program is in the process of continued refinement.

## APPROACH

This project was intended to develop the data that will assist in evaluating the validity of the 60-second time limit for dry pipe sprinkler systems. The following approach was used:

- Relevant available loss experience data, test reports, and research studies were collected and reviewed. Information was sought from NFPA, NFPA technical committees, industry sources, and other domestic or international literature sources. Previous code proposals and comments, and recent public hearing comments, were reviewed to identify the issues, concerns and industry perspectives regarding keeping or deleting the historical exception for omitting water delivery times for small dry pipe sprinkler systems less than 500 gallons (750 gallons with a Quick Opening Device).
- Listed fluid delivery time calculation software was used to determine the trip times with single long lengths of 1", 1¼", 1½" and 2" pipes with various orifice sizes. While this configuration does not represent a common real world configuration, it should trend towards a maximum trip time and provide an upper limit in the evaluation.
- "Typical" layouts for several sprinkler systems with 500 gallon and 750 gallon capacity were evaluated. One configuration considers 2 sprinklers on each branch line (1 each side of the cross main). A second configuration used 8 sprinklers on each branch line (4 each side of the cross main), and a third configuration used 16 sprinklers on each branch line (8 each side of the cross main). The fluid delivery time software was used to determine the trip time and water delivery time for the different configurations with different water supplies.
- Limited fire modeling was performed using Fire Dynamics Simulator (FDS) software to determine the number of sprinklers opened prior to the time of water delivery for selected growth fire scenarios and the given "typical" sprinkler layouts. Fires are located in a corner arrangement and in an open area arrangement to test the variation in number of heads opening due to room geometry, wall/enclosure effects and fire location.
- A comparison of the results of the software calculated water delivery times and the FDS sprinkler operation results is provided. The comparison considers the area of operation of sprinklers verses the required design area of the postulated dry sprinkler systems at the predicted time of water delivery. This comparison intends to show whether the number of fused sprinklers, based on fire modeling results, has exceeded the design area or is encroaching on the limit of the design area.
- This report will identify gaps and research needed to further develop potential changes to NFPA 13.

## OBSERVATIONS FROM LITERATURE REVIEW AND GAP ANALYSIS

The principal observations and gaps in the data and research are most apparent when reviewing

- the available data on installed dry pipe systems, and
- the evaluation of water delivery times verses FDS sprinkler activation results.

From the literature review two sources of actual full scale dry pipe system data are identified.

1. The Zimmerman article provides data for relatively large volume dry pipe systems of 1000-1600 gallons. The associated dry pipe trip times of systems without a quick opening device (QOD) ranged from 22 second to 84 seconds and water transit times (after trip) ranged from 27 seconds to 59 seconds for water delivery to an inspector's test connection. It is important to recognize that the inspector's test connection in these test were comparatively large using 1" to 1½" openings at the

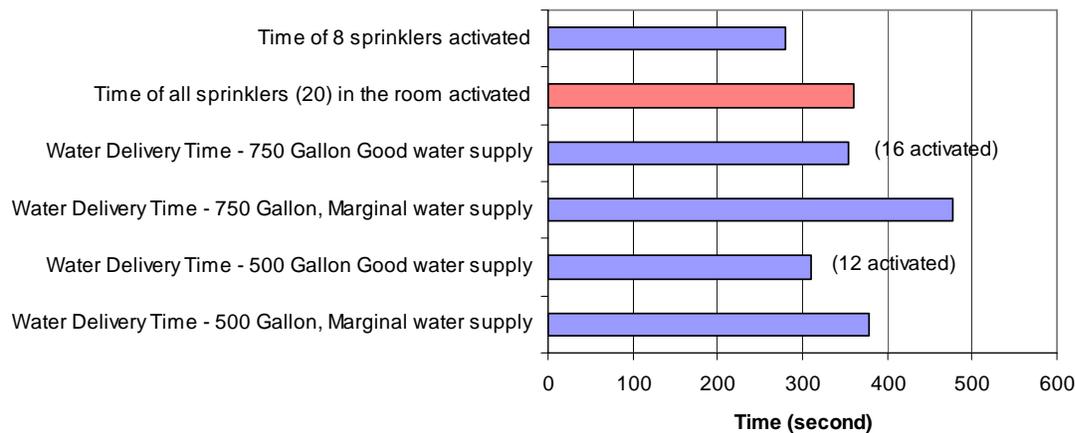
inspector's test connection. In comparison a ½" outlet as would be required for most systems has a cross sectional area of 0.151 in<sup>2</sup> versus a cross sectional area of 0.864 in<sup>2</sup> for the 1" outlet used in the Zimmerman article. The 1" opening used is approximately equivalent to four large orifice sprinklers and therefore is the primary contributor to the relatively short trip and water delivery times for times for the 1000-1600 gallons dry pipe systems. In the only three tests of the dry pipe systems using a ½ " outlet with a QOD, the water transit times were 103, 62 and 78 seconds. Again, this illustrates that better performance was achieved with the 1" outlet (equivalent of 4 sprinklers) than having a system with a ½ " outlet with a QOD.

2. The thesis by Valentine provides both water delivery results for a full scale dry pipe system constructed at Underwriters Laboratories (UL) and provides a glimpse of sprinkler performance for a single fire scenario using both FDS modeling and full scale fire tests. The scenario used considered Standard FMRC Group A Plastic Commodity, Boxes Stacked 6' 8" high. The commodity was burned under a 20 ft. high ceiling with both quick response (QR) and standard response (SR) sprinklers spaced 10 ft. x 10 ft providing a 0.19 gpm/ ft<sup>2</sup> density with sprinklers having a k-factor of 5.6. The system design area was 3300 ft<sup>2</sup>. The FDS-based results showed a total water delivery time of 50-59 seconds (based on t=0 at first open sprinkler) to the postulated sprinklers with 24 QR and 12 SR sprinklers opened at the time of water delivery. The full-scale tests showed a total water delivery time of 65-72 seconds (approx. 15 seconds greater than FDS results based on t=0 at first open sprinkler) to the installed sprinklers with as many as 19 QR and 13 SR sprinklers opened at the time of water delivery. It is important to note that as many as 5 sprinklers continued to open after first water delivery in the full scale tests. The full scale tests conducted at UL was the first significant attempt to address and tie the water delivery performance to successful sprinkler control performance.

It is apparent from the available literature that the water delivery time limit of 60 seconds has some, but not overwhelming data to support requiring or not requiring a time limitation for small systems. The only full scale research done to date at UL is demonstrative, but limited for the following reasons.

- Dry pipe sprinkler systems water delivery performance can vary widely due to factors of piping design layout, change of conditions due to potential corrosion in aged systems, orifice size, number of initially opened sprinklers, system pressure, and water supply characteristics. The potential number of variations of these conditions suggests that the analysis and limited full scale testing reported by Valentine neither adequately cover the universe of dry pipe system performance nor do the single fire scenario tests point to trends that can be comfortably extrapolated to all dry systems.
- The full scale tests performed at UL provide a narrow basis to conclude that all dry pipe systems will perform successfully. The full-scale tests only considered a single fire scenario conducted in a relatively large open space (100' x100') and considered a single ceiling height scenario (20 ft). Dry pipe systems are often utilized to protect irregular spaces that will have enclosing walls on all sides or the dry system may be protecting an area that is largely an outdoor area. The UL tests do not account for sensitivities in sprinkler operating times that would be expected for smaller enclosed spaces with lower ceiling heights (8-12 feet) while having fuel arrangements that present rapid fire growth scenarios.
- In the full scale tests performed at UL the area of sprinkler design operation was 3300 ft<sup>2</sup>. The number of operating sprinklers used to conclude successful dry pipe system operation was 19 QR and 13 SR sprinklers representing approximately 60% (1900 ft<sup>2</sup>) and 40 % (1200 ft<sup>2</sup>) of the operating area of 3300 ft<sup>2</sup>. It should be recognized that the fire development used in the UL tests is a plausible fire growth scenario for dry pipe systems designed to lesser criteria, such as 1950 ft<sup>2</sup> design areas common for many light and ordinary hazard sprinkler systems. Consequently, it is reasonable to expect that such similar fire growth scenarios under light and ordinary hazard sprinkler systems could result in numbers of sprinklers opened beyond the design area limits. The effects of enclosing walls and lower ceiling heights would contribute to more open sprinklers than realized in the UL tests.

The commentary above addresses the lack of comprehensive data available from the full scale testing performed to date. To test some of noted concerns for lower ceilings and wall/enclosure effects this report provides some limited analysis of water delivery times verses FDS sprinkler activation results. The implications of the data found in this report's section titled "Modeling Analysis of Dry Pipe System Performance" can be explained by example of the following bar graph. The bar graph below illustrates the possible negative performance of a dry pipe system having a design area of 1950 ft<sup>2</sup> with 17 design area sprinklers in a room of 2400 ft<sup>2</sup>. The scenario used assumes a medium growth T-squared fire and standard response sprinklers installed under a 9 ft. ceiling. At the time of water delivery it is indicated that virtually all sprinklers in the room have activated in all but one scenario, that being the 500 gallon system with a "good" water supply (shows only 12 sprinklers open.) Given that the UL full scale tests showed sprinklers continuing to open after water delivery, it could be expected that more sprinklers would be open than indicted by the FDS results for this same 500-gallon system scenario.



Currently, only one series of full scale fire tests (three tests at UL) exist that examine the relationship between dry pipe water delivery time and dry pipe sprinkler system performance. Although these full scale tests indicate successful sprinkler control mode performance for the specific and limited conditions of the full scale tests, a limited modeling analysis of dry pipe system water delivery times and associated sprinkler operating times indicates that ceiling height, wall/enclosure effects and piping configuration variations can be expected to result in more sprinklers opening than the system was designed to accommodate by NFPA 13 requirements. Based on these findings and the identified limitations of the research conducted to date the following additional studies are recommended.

1. **Additional Full Scale Testing:** The 60-second rule for water-delivery time, the exemptions for limited-size systems and the NFPA 13 table for use in conjunction with the computer program have not been sufficiently examined and tested against actual fire development under varying conditions. Full scale testing should be performed to identify the impact of lower ceiling heights, wall enclosure effects, water supply and sprinkler orifice size on water delivery times and dry pipe sprinkler system performance.
2. **Benefit of Larger Orifice Sprinklers:** The benefit of using and/or requiring sprinkler orifice sizes greater than ½ in. should be explored as an alternative to installing quick opening devices (QODS) commonly used to speed the trip time and expulsion of pressurized air from dry pipe systems.
3. **Reliability of QODs:** Research should be conducted to evaluate the reliability of QODS, most specifically accelerators. Authors of the literature reviewed, herein, and the in-field experience of the authors of this report note that QODs appear subject to a relatively high failure rate that may have negative influence on the level of successful performance of dry pipe systems relative to wet pipe systems. The trip tests of dry pipe systems reviewed by Zimmerman show that the difference between a dry pipe system trip times with and then without a QOD are on the order of 50 -60

seconds, a time frame in which the number of open sprinklers could double or triple after the initially opened sprinklers (e.g., first ring of sprinklers).

4. **Listed Software Development:** More software development is needed. The one currently available computer program for calculating delivery times, SprinkFDT, has been investigated under UL Subject 2432, which requires that calculated trip times, transit times, times to operating pressure, and water delivery times correlate closely with measured observations of experimental dry-pipe systems. Actual field experience with using the software program and correlating the results to measurements on installed systems corresponding to the program model appear to be limited. Documented and undocumented limitations in the fluid delivery time software used to evaluate water delivery time for this report leaves a void in the design allowance of NPFA 13 to use a listed program. The software is currently limited to tree systems with a single cross main. The software is currently limited to tree systems with a single cross main. (Note: At the December 2006 industry meeting, it was reported that the software was under constant updating and that the most current release has addressed the “crashing problem” and the need to reset the trip time for each iteration.)
5. **Long Term Dry Pipe Interior Conditions:** Additional study is warranted on the long term interior corrosion possible in dry pipe sprinkler systems and the impact that increased corrosion rates may have on water delivery in aged, potentially excessively corroded dry pipe systems.

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